# Performance and Safety Testing of Lithium-ion cells Containing Flame-Retardant Additives

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Lithium-ion batteries have been commercially available for over ten years,[1] and they are being utilized in an ever-expanding number and scope of applications. Large sized cells and batteries are currently in development for applications such as electric vehicles, aircraft, satellites, and planetary exploration. The lithium-ion technology offers a high energy and power density, long life and reliability that makes it attractive for many commercial, military, and aerospace applications. One of the lingering concerns about the technology is the safety associated with the system. Especially in liquid electrolyte systems, but also to a certain extent in most gel polymer and many solid polymer systems, the flammability of the electrolyte and other components poses a safety concern. Several methods of limiting and/or preventing safety events have been developed, such as smart battery control electronics, poly-thermal switches (PTC) and pressure switches, however, these devices are typically external to the cell or built into the cell in a way that decreases the energy density or specific energy of the cell. Several chemical additives have been developed to improve the lithium-ion chemistry response to abuse conditions. These include overcharge shuttle redox systems, shutdown separators, and, recently, flame retardant additives.

Various flame-retardant additives have been proposed for use in secondary lithium and lithium-ion cells. Many phosphate or phosphorous containing compounds have been tested[2,3,4], as well as some acid halide and halide containing components[5]. Much of the work on these systems has demonstrated little to no degradation of electrolyte conductivity or the cycling efficiency of lithium half-cells. All of this work reports the thermal behavior of cells and cell components with and without the particular additives. These typically demonstrate the significant extent to which the released energy of the thermal event is reduced or the onset temperature is increased. However, very little of this work shows the effects of cycling and safety testing of actual lithium-ion cells containing the additives.

This paper will present the preliminary results of cell testing and safety/abuse testing of full lithium-ion cells containing various flame-retardant additives. The goal is to demonstrate the real-life viability of such components and the true safety benefits of their addition. This work focuses on the use of phosphates and phosphorous containing additives as a starting point for a larger investigation.

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